APCOM & ISCM
11-14th December, 2013, Singapore

Simulation on Fluctuation of Water Surface in Ship Lift Chamber with Tumble Gate Opening

Z.H. Gu[1], X.M. Cao[1], and Jane W.Z. Lu[2]*

[1]Colledge of Civil Engineering and Architecture, Zhejiang University, Zhejiang, China
[2]Department of Civil and Architectural Engineering, City University of Hong Kong, Hong Kong, China
*Corresponding author: Tel: +852 34424316, Fax: +852 34420427, bcwzlu@cityu.edu.hk

Abstract

Ship lift is a common navigation structure, which utilizes mechanical power to drag the chamber to overcome the concentrate water level in waterway. It is known as "elevator of ship" and widely used in high dam navigation (Tu, et al., 2008). Currently, the largest ship lift in the world is "Three Gorges Ship Lift" in China. Opening tumble gate is the indispensable step during ship lift operation. In this process, water in chamber is disturbed largely and forms fluctuation (Bao and Chen, 1998; Cui and Zhang, 2006). If there is a ship in the chamber, the fluctuation can further impact stress state of ship and cables (Fig. 1). With improper operation, cables may be breakage, ship may be out of control and ship lift may be loss of stability in longitudinal direction (Gu, 2000, 2002, 2007). As a consequence, the hydrodynamic problem on ship lift chamber upon tumble gate opening is very worthy of attention. Upon ship lift chamber docking with approach channel in the case of water level difference, water in chamber will fluctuate evidently. In actual operation process of ship lift, due to human control error and other reasons, there is usually a level difference between chamber and approach channel. Under this circumstance, water in chamber may form dramatic fluctuation upon opening the chamber tumble gate. The maximum or minimum fluctuation of water surface is an important parameter to measure operational safety of ship lift.

In this study, a simplified 3D mathematical model (Fig. 2) of ship lift chamber upon tumble gate opening was built based on standard k-ε model, FVM (finite volume method), VOF (volume of fluid) model implemented with local refined meshes (Daniel and William, 1980; Wang, et al., 2011). The numerical results are verified with the corresponding experimental measurements and present good compliances. According to experimental model data, error correction from simplified to actual was discussed and obtained correction formula. Through dimensional analysis, three influence factors -- d/B B/L and Δh/d -- of $\Delta h_{max}/d$ and $\Delta h_{min}/d$ are determined, based on which influence laws of each factor are analyzed respectively. Finally empirical formulas of $\Delta h_{max}/d$ and $\Delta h_{min}/d$ are fitted by SPSS and modified by correction formula. The results have practical value for engineering design and security operation of ship lift.

Keywords: Ship lift, Chamber, Water wave, VOF model, FVM, CFD

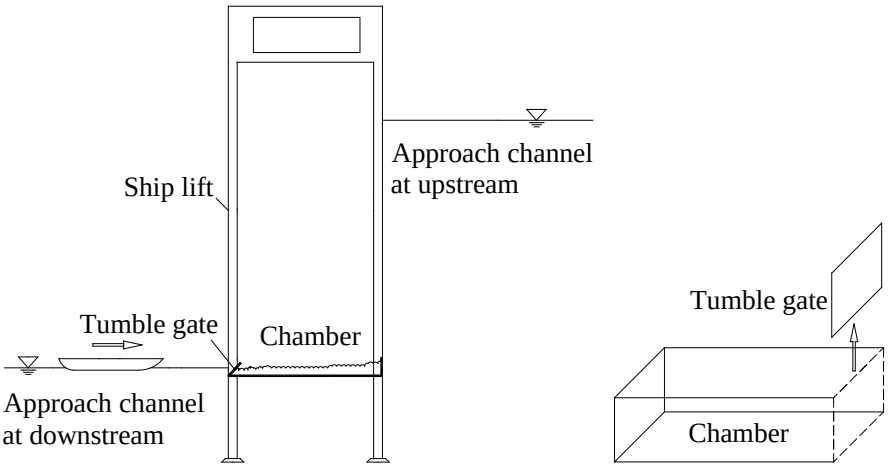

Fig. 1 Hydrodynamic problem on tumble gate opening (L), simplified gate opening (R)

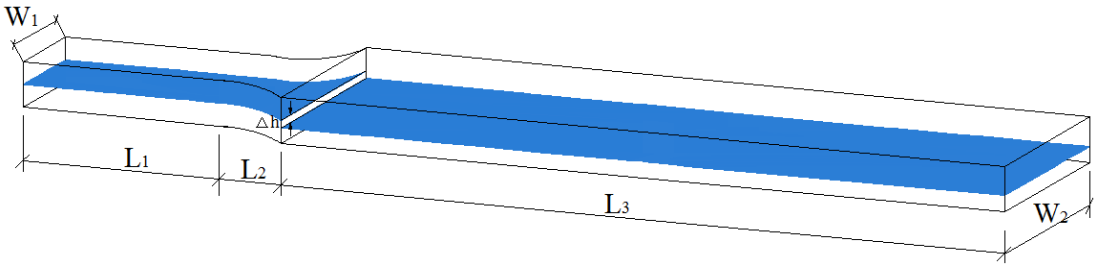

Fig. 2 Simplified flow model

Acknowledgment

The project supported by Hong Kong RGC-GRF Grant (CityU 118212), Strategic research grant, City University of Hong Kong [Projects No. CityU-SRG 7002718], National Natural Science Foundation of China (Grant No. 50909085) & Science and Technology Project of DWRZJ (Grant No. RC1106).

References

1. Bao, GJ and Chen, JZ, 1998. Probe into hydrodynamics problems of hoisting vertical ship lift. *Hydro-Science and Engineering*. 4, pp. 397-403.
2. Cui, Z and Zhang, X, 2006. Flow simulation of spur dike using 3-D turbulent model. *Engineering Journal of Wuhan University*. 39(1), pp. 15-20.
3. Daniel, RL and William, GG, 1980. Finite element simulation of flow in deforming regions. *Computational Physics*. 36(2), pp. 135-153.
4. Gu, ZH, 2000. Experimental study on hydrodynamic of ship lift chamber. Master Degree. Nanjing Hydraulic Research Institute.
5. Gu, ZH, Bao, GJ, Xuan, GX and Chen, JZ, 2002. Experimental study on hydrodynamic characteristics of ship lift chambers. *Hydro Science and Engineering*. 3, pp. 7-13.
6. Gu, ZH, Liu, GP, Tang, HW, Zhou, YL, 2007. Study on numerical simulation of water transfer process in tidal river networks. *Journal of Hydroelectric Engineering*, 26(4), 76~85.
7. Wang, XY, Yang, QY, Lu, WZ, Wang, XK, 2011. Effects of bed load movement on mean flow characteristics in mobile gravel beds, *Water Resources Management*, 25(11): 2781-95, doi: 10.1007/s11269-011-9838-6.
8. Tu, JW, Qu, WL and Chen, J, 2008. An experimental study on semi-active seismic response control of a large-span building on top of ship lift towers. *Journal of Vibration and Control*. 14(7), pp. 1055-1074.